TECHNICAL REPORT

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INFRARED ALGORITHM DEVELOPMENT FOR OCEAN OBSERVATIONS WITH EOS/MODIS

Abstract

Efforts continue under this contract to develop algorithms for the computation of sea surface temperature (SST) from MODIS infrared retrievals. This effort includes radiative transfer modeling, comparison of *in situ* and satellite observations, development and evaluation of processing and networking methodologies for algorithm computation and data accession, evaluation of surface validation approaches for IR radiances, development of experimental instrumentation, and participation in MODIS (project) related activities. Activities in this contract period have focused on radiative transfer modeling, evaluation of atmospheric correction methodologies, analysis of field data, objective analysis approaches, revision of the ATBD and participation in the ATBD review process, and participation in MODIS meetings.

MODIS INFRARED ALGORITHM DEVELOPMENT

A. Near Term Objectives

A.1. Continue algorithmic development efforts based on experimental match-up databases and radiative transfer models.

A.2. Continue interaction with the MODIS Instrument Team through meetings and electronic communications, and provide support for MCST pre-launch calibration activities.

A.3 Continue evaluation of different approaches for global SST data assimilation and work on statistically based objective analysis approaches.

A.4 Continue evaluation of high-speed network interconnection technologies.

A.5 Continue development of *in situ* validation approaches for the MODIS IR bands.

A.6 Provide investigator and staff support for the preceding items.

B. Overview of Current Progress

B.1 July-September 1997

Activities during the past three months have continued on the previously initiated tasks. There have been specific continuing efforts in the areas of (a) radiative transfer modeling, , (b) continued work on IR calibration/validation as part of the MODIS Ocean Science Team cruise effort, (c) analysis of consequences of imperfect pre-launch characterization of the MODIS infrared channels, and (d) test and evaluation of an experimental wide area network based on ATM technology. In addition, previously initiated activities such as team related activities continue.

Special foci during this three month period have been:

1) AVHRR *in situ* comparison data base studies.
2) Continue analysis of measurements from the DOE/NOAA/NASA ARM Combined Sensor Project cruise in the Tropical Western Pacific in the spring of 1996.
3) Construction of a marine FTIR instrumentation for cal/val applications by UW/SSEC via subcontract .
4) Negotiate for ship-time for post-launch validation, and explore options for long-term validation from fixed platforms.

B.1.1 Radiative Transfer Modeling

The RAL line-by-line radiative transfer model was used with a global dataset of 1200 quality-controlled radiosondes over 5 zenith angles and 5 atmosphere-surface temperature differences to generate a database of 30000 brightness temperatures in each of MODIS bands 31 and 32. Colleagues at RSMAS have developed the Miami Pathfinder SST (mpfsst) algorithm , which is the basis for the MODIS V.2 pre-launch SST algorithm:

$$modis\_sst = ((c_2 * T_{30}) + (c_3 * T_{3031}) + (c_4 * secterm) + c_1)$$

$$secterm = ((1 / (\cos ((satz * pi) / 180))) - 1) * T_{3031}$$

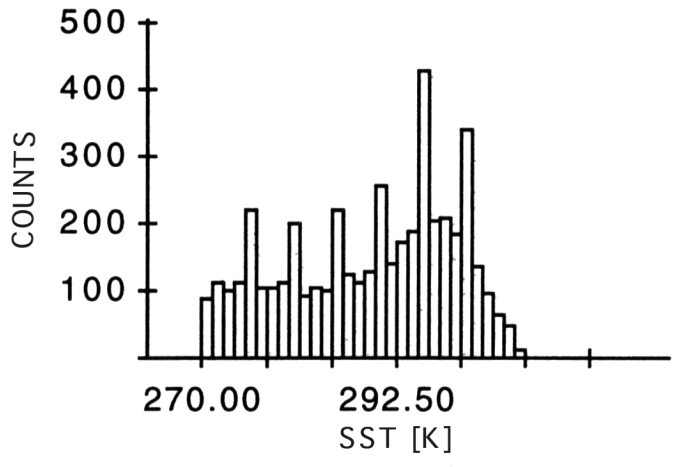
T_{30} is the band 30 brightness temperature (BT). (Comparable to AVHRR Channel 4)
T_{3031} is (Band30 - Band31) BT difference (Comparable to AVHRR (Channel 4 - Channel 5)).

The algorithm differentiates atmospheric vapor load using the difference between the brightness temperatures (T_{3031}) for the 11 and 12 micron bands (MODIS bands 30 and 31). Coefficients are determined for T_{3031} greater or less than 0.7 C. In application, the coefficients are then weighted by measured T_{3031}.

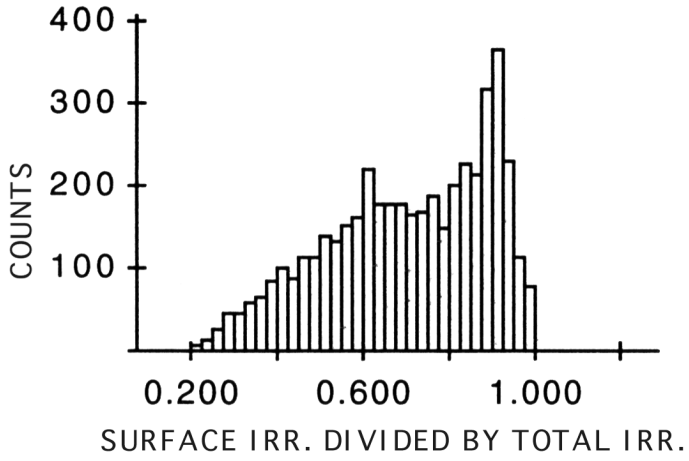
The 30000 point database was run through a robust regression to fit the *modis_sst*. Data are weighted according to the residuals, discarding data more than one Standard Deviation from the basic regression. A subsequent regression derives the coefficients. Residuals of that regression increased notably for Arctic and Antarctic terrestrial stations with surface temperatures below -2°C, which would be unrealistic temperatures for marine atmospheres. Excluding those extremely cold data, the series of regressions were re-run. MODIS V.2 pre-launch *modis_sst* coefficients were delivered with a predicted RMS error of 0.337K about zero mean error.

At-Launch Coefficients		
	$T_{30} - T_{31} <= 0.7$	$T_{30} - T_{31} > 0.7$
c_1	1.228552	1.692521
c_2	0.9576555	0.9558419
c_3	0.1182196	0.0873754
c_4	1.774631	1.199584

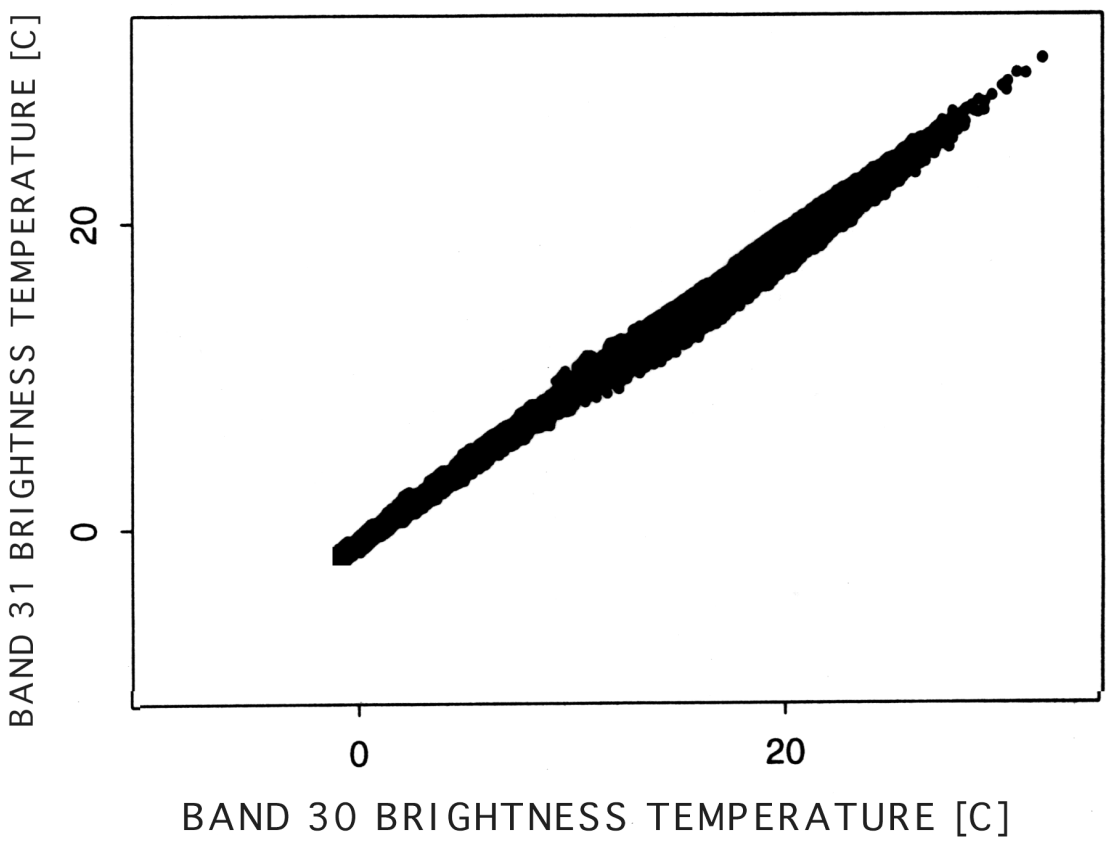
While the radiosonde database was somewhat biased toward warmer SST's and clearer atmospheres, this bias was reduced by the statistics-based rejection of outliers. The plot of modeled band 31 *vs*. band 32 resembles the distribution of previously collected Pathfinder data. Residuals showed no major trend *vs*. zenith angle or SST. Residuals are greatest at high latitudes.



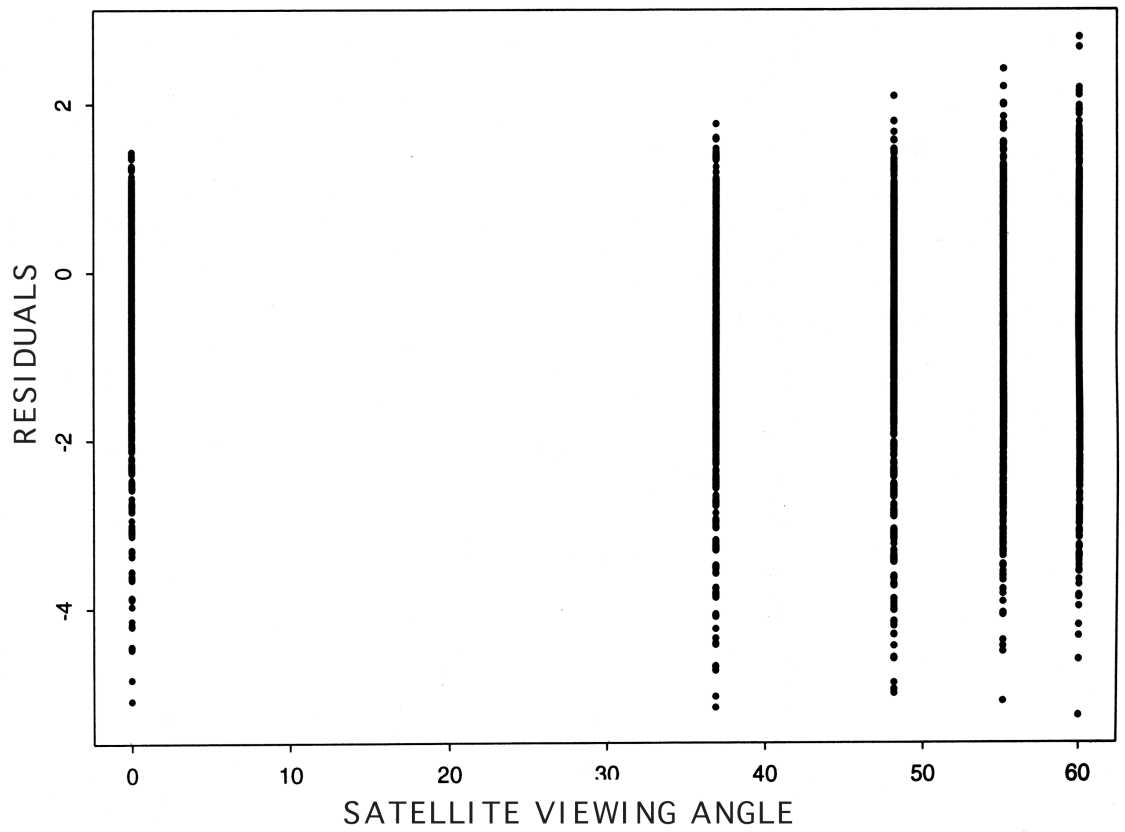
The modeled brightness-temperature database, filtered to remove surface temperatures below -2 C, is show fairly uniform distribution versus surface temperature.



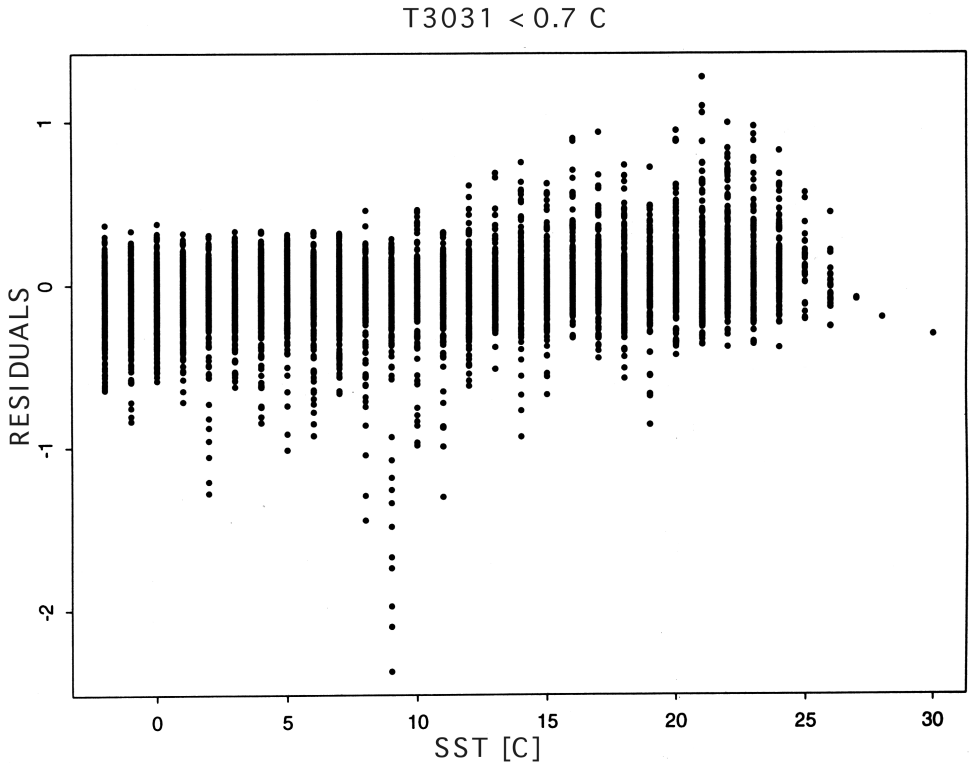
The modeled brightness-temperature database, filtered to remove surface temperatures below -2 C, is show fairly uniform distribution versus atmospheric clarity, represented as fraction of surface-leaving irradiance divided by total satellite-viewed irradiance in band 31.

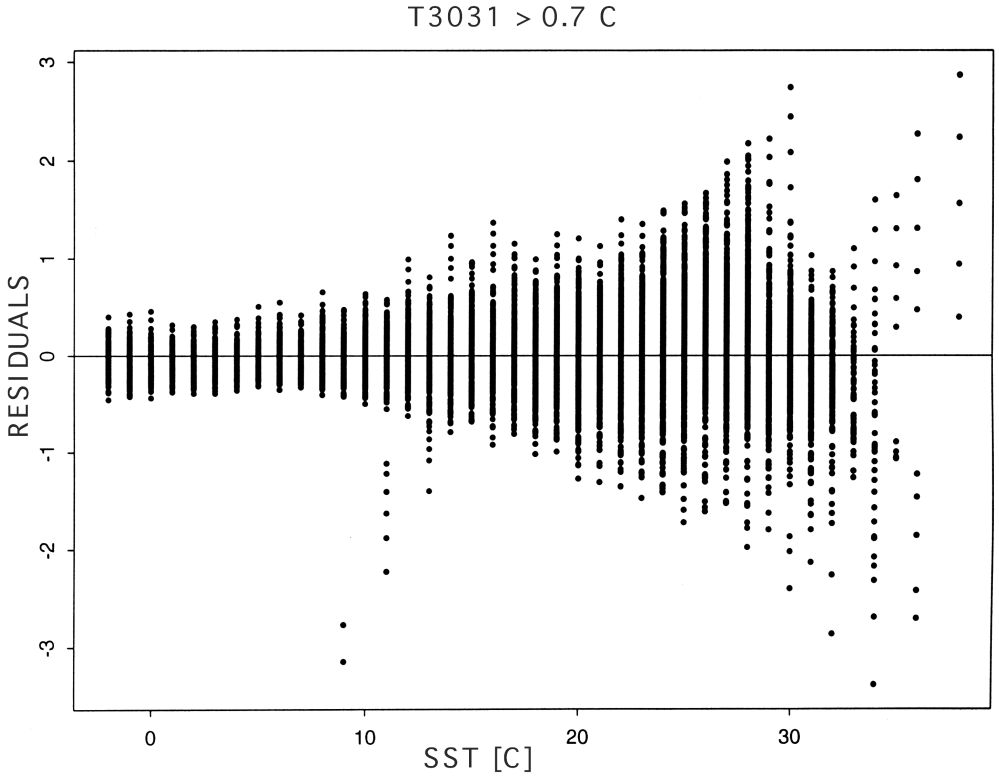


Modeled modeled brightness-temperatures for band 30 (11 µ window) versus band 31 (12 µ window) shows a spreading of values above 15 C, which is typical of measured Pathfinder data.

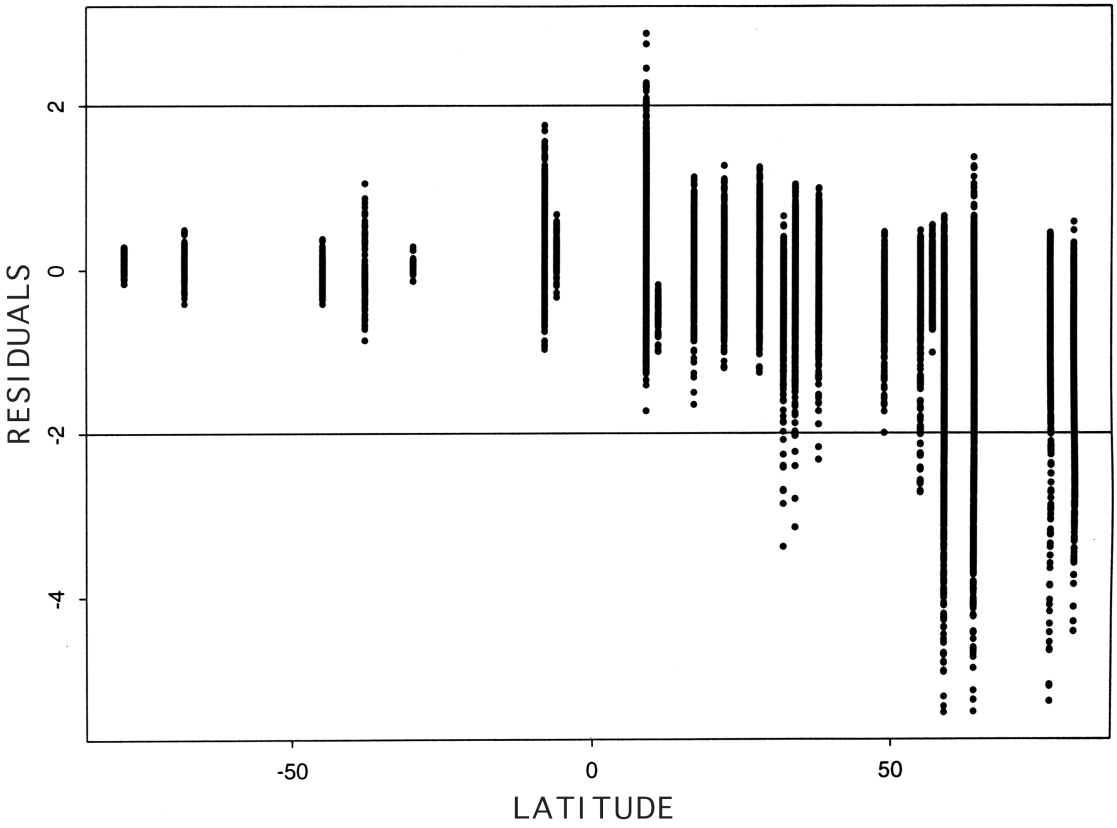


Residuals from the least-squares regression for the MODIS V.2 pre-launch algorithm show no major trends versus satellite zenith angle. (Surface temperatures > -2 C)





Residuals from the least-squares regression for the MODIS V.2 pre-launch algorithm show no major trends versus SST, with T3031 greater or less than 0.7 C. (Surface temperatures > -2 C)



Residuals from the least-squares regression for the MODIS V.2 pre-launch algorithm are greatest at high latitudes. (Surface temperatures > -2 C)

B.1.2 The Combined Sensor Cruise of the NOAA ship *Discoverer*

As described in earlier reports, the Combined Sensor Cruise in the Tropical Western Pacific in March–April 1996, generated an unprecedented array of measurements of atmospheric boundary layer and sea surface temperature.

Attention has been focused on the quality assurance of the prototype M–AERI skin SST retrievals to generate a final, clean time series. Jennifer Hanafin (graduate student) visited SSEC, University of Wisconsin - Madison, to work on the identification of suspect retrievals. The final data set will be released soon. While at SSEC Jennifer was also given training on the operation of the M–AERI control software in preparation for the forthcoming cruise on the *R/V Revelle*.

B.1.3 Future validation campaign (at sea cruise) planning

R/V Revelle Cruise

Preparations are underway to participate in the cruise of the *R/V Revelle*, leaving Honolulu on September 28 and arriving in Lyttleton, New Zealand, October 14. This cruise will cover a wide range of climate regimes (21.5°N to 43.5°S) over a distance of ~7,900 km.

The second M–AERI will be delivered to the RSMAS group in time for this cruise and it is planned

to operate two M–AERIs side by side during the passage to New Zealand. This will permit evaluation of the absolute accuracies of the measurements and allow us to test different sampling schemes on one while maintaining a "default" scheme on the other. A full suite of supporting instruments are ready for deployment during the cruise.

CCGC *Louis S. St. Laurent*

The Canadian research agency NSERC has funded the scientific voyages of the Canadian icebreaking research vessel *Louis S. St. Laurent* to the north of Baffin Bay (see earlier report). A meeting was held at the University of Winnipeg for scientists involved in the physical (as opposed to biological and geochemical) aspects of the cruise, and Dr. Minnett attended this meeting. The berths will be allocated at another meeting of all cruise participants, to be held in late November.

B.1.4 M-AERI

The M–AERI–01 delivered to RSMAS in April has been running satisfactorily in the lab since then. The control computer has been put on to the RSMAS network to allow the specialists at SSEC to monitor the state of the instrument. The only cause for concern is instabilities in the current being drawn by the Stirling cycle cooler, which chills the detectors to ~78°K. This behavior has not been seen in other coolers, but does not appear to cause fluctuations in the detector temperature.

The M–AERI–02 and M–AERI–03 are scheduled for delivery before the end of September. M–AERI–02 will be used on the *R/V Revelle* (see B.1.3) while M–AERI–03 will remain at SSEC to act as a test-bed for improvements that are anticipated to be necessary as a result of experiences of the *Revelle* cruise. The detectors on the two new M–AERIs have better noise characteristics than those of M–AERI–01 and it is anticipated that this will lead to faster sampling as fewer independent interferograms will be needed to determine each spectrum.

B.1.8 Wide Area Networking

Since the last report a second gigaswitch ATM has been added; the two switches are being interconnected using OC12 (622Mbs) links. Additional hardware to populate the second switch and workstation interfaces were acquired. These changes allow the existing ATM network to be expanded to cover at-launch requirements.

C. Investigator Support

July	W. Baringer	A. Li
	J. Brown	A. Mariano
	O. Brown	R. Sikorski
	P. Evans	J. Splain
	G. Goni	
August	W. Baringer	G. Goni
	J. Brown	A. Li
	O. Brown	A. Mariano
	P. Evans	R. Sikorski
September	W. Baringer	G. Goni
	J. Brown	A. Mariano
	O. Brown	R. Sikorski
	M. Framinan	

D. Future Activities

D.1 Current:

D.1.1 Algorithms

a. Continue to develop and test algorithms on global retrievals
b. Evaluation of global data assimilation statistics for SST fields
c. Continue radiative transfer modeling using RAL code
d. Continue analysis of Combined Sensor Cruise, data
e. Continue to study near-surface temperature gradients
f. Continue planning of post-launch validation campaigns.
g. Validation Plan updates (as needed)
h. EOS Science Plan updates (as needed)
i. Define and implement an extended ATM based network test bed
j. Evaluate and analyze results of calibration/validation experiment
k. Continued integration of new workstations into algorithm development environment
l. Continued participation in MODIS Team activities and calibration working group.

D.1.2 Investigator support

Continue current efforts.

D.1.3. AGU Meeting

Dr. Peter Minnett has been invited to present a paper on the measurement of sea surface temperature at the forthcoming Fall meting of the American Geophysical Union in San Francisco in December.

E. Problems

No new problems to report.

F. Publications and Presentations

None this quarter.